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RECEIVED

February 28,1995

FEB 2 8 1995

COM ROOM

Office of Secretary
Federal Communications Commission
1919 M Street, N.W.
Washington,D.C. 20554

Re: ET Docket No . 94-124
RM-8308

DOCKET FILE COPY ORIGINAL

In the Matter of
Amendment of the Parts 2 and 15
of the Commission's Rules to permit
Use of Radio Frequencies Above 40 GHz
For New Radio Applications

Dear Secretary:

In compliance with your request ET Docket No . 94-124, we enclose the following documents.

"Additional Comment on the Reconsideration of Vehicular Radar Bands"
one(1) original and nine (9) copies

If additional information is required concerning this matter, please let us know.(Contact person is Mr. Masayoshi Wakao of RCR.)

Sincerely yours,

Hiroshi Kojima
Secretary General

Enclosure

In the matter of   )   FEB 2 8 1995

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)   FCC MAIL ROOM
Amendment of Parts 2 and 15   )
of the Commission's Rules to Permit) ET Docket No. 914-124
Use of Radio Frequencies Above 40 GHz) RM-8308
for New Radio Applications   )

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TO: The Commission

Additional Comment on the Reconsideration of Vehicular Radar Bands

Background

1. On January 27, 1995, the Association for the Promotion of Millimeter-Wave Development and Utilization (APMDU) asked the Federal Communications Commission (FCC) to allocate the 60-61 GHz band exclusively to vehicular radar systems. We studied the possibility of vehicular radar systems and unlicensed devices sharing frequencies in the 60-61 GHz band. The result of this study is presented here as an additional comment.

Interference to vehicular radar systems from unlicensed devices

2. The interference imposed by unlicensed devices on vehicular radar systems is discussed in the Appendix. Suppose that the equivalent isotropically radiated power (EIRP) of vehicular radar systems and unlicensed devices is determined in accordance with the Notice of Proposed Rule Making (NPRM). If an unlicensed device is within 160 m from a vehicular radar system, the vehicular radar system is likely to report incorrect distances or speeds because the carrier-to-interference power ratio (CIR) is insufficient for correct signal detection.

The discussion in the Appendix, however, is likely to be pessimistic because it assumes that the antennas of the vehicular radar system and the unlicensed device face each other and that their antenna beams are aimed in the same direction.

3. As discussed in the Appendix, when the gain of the antenna used for the vehicular radar system is 36 dB, the half-power beamwidth of the antenna is about 2.3 degrees. When the area where the unlicensed device interferes with the vehicular radar system is estimated from this half-power beamwidth, it is found that the area at a distance of 160 m from the vehicular radar system is a pinpoint and the area at a distance of 110 m has a radius of as small as 2.2 m. In addition, before an unlicensed device can cause interference in a vehicular radar system, the beam from the unlicensed device must be directed toward the vehicular radar system. This situation seems rare in that the unlicensed device must be installed on a highway.

It can therefore be concluded that vehicular radar systems are very unlikely to malfunction because of interference from unlicensed devices.

4. Interference between vehicular radar systems is more likely than interference between a vehicular radar system and an unlicensed device. This is because the EIRP of vehicular radar systems is at least 20 dB greater than that of unlicensed devices. In addition, the main lobes of the radar antennas often coincide, as in the case of vehicular radar systems mounted on automobiles which are traveling in opposite lanes.

To lessen such severe interference, vehicular radar systems will be designed to reduce both interference from other vehicular radar systems and interference caused in other vehicular radar systems. Some techniques for interference reduction will also help reduce interference from unlicensed devices.

5. The following techniques help reduce interference from both vehicular radar systems and unlicensed devices.

As long as the receiver of a vehicular radar system is not saturated by interference waves, the equivalent interference bandwidth can be narrowed through the use of fast Fourier transform (FFT) for spectrum analysis on received signals. For example, immunity to interference can be increased by no less than 18 dB by sampling the received signal for spectrum analysis at 64 points. (The acceptable interference level denoted by the dashed line in the chart given in the Appendix must be read as -36.6 dBm). This means that the distance in which a vehicular radar system is affected by interference can be reduced by a factor of 5 when compared with the case where FFT is not used.

Another technique is averaging. Interference can be further reduced by averaging the data measured by the vehicular radar system over around 10 cycles.

Both the FFT and averaging techniques can easily be accomplished by using a digital signal processor (DSP). Inexpensive DSP chips are also available.

Interference from vehicular radar systems on unlicensed devices

6. The degree of interference caused by vehicular radar on unlicensed devices cannot be analyzed unless the detailed parameters of the unlicensed devices are available. It can be said, however, that even though a vehicular radar system interferes with an unlicensed device, the period of this interference is short because the vehicular radar system is mounted on a fast-moving automobile. In addition, since vehicular radar systems are used on roads, only limited areas will be subject to their interference.

7. Since some network has a means for retransmission, some applications may be free from short-time interference. For example, radio LANs and other packet communication

systems can prevent users from noticing interference even though communication is interrupted for a short period because of interference. Obviously, a slight reduction in throughput, however, is involved.

Conclusion

8. The possibility of sharing frequencies by vehicular radar systems and unlicensed devices has been studied. The study revealed that it is very unlikely for unlicensed devices to seriously interfere with vehicular radar systems. In addition, since vehicular radar systems are mounted on moving automobiles, it seems that their interference on unlicensed devices is limited in terms of time and place.

Our conclusion from this discussion is that vehicular radar systems and unlicensed devices can share frequencies.

APPENDIX

This appendix reports on our investigation of an interference from an unlicensed device to a vehicular radar system. There are many types of radar systems, FM-CW radar, pulse-doppler radar, duplex radar, and spread spectrum radar. We considered only FM-CW radar .

1. Minimum received signal power

It is well known that the received signal power of a radar receiver is:

$$\mathrm{Pr} = \frac{PtG^2\lambda^2\sigma}{(4\pi)^3 R^4 La}$$

where:

   Pr : received signal power (at antenna terminals)

   Pt : transmitted signal power (at antenna terminals)

   G : antenna power gain

   λ : wave length

   σ : radar target cross section

   R : radar-to-target distance (range)

   La : absorption

We assume that the maximum detection range of the radar system is 100 m. The other radar conditions are:

$Pt\,G$ (EIRP of a radar transmitter) = 46 dBm

$G = 36$ dB

$\lambda = 5$ mm (60 GHz)

$\sigma = 10$ dB

$La = 3.2$ dB/200 m

The minimum received signal power at the maximum detection range is -70.6 dBm.

Let the required ratio of Pr and an interference power level from the unlicensed device be:

$$Pr/\,I \ge 10$$

The acceptable interference power level is less than -80.6 dBm.

2. Interference bandwidth of a radar receiver

Second, we will obtain the bandwidth of an FM-CW radar receiver.

The beat frequency generated by mixing a reflected signal from a target and a local oscillator signal of a radar receiver is

$$f_r = \frac{4Rf_m\Delta f}{C}$$

where

f_r : beat frequency

f_m : repetition frequency of modulation signal

Δf : frequency deviation

C : velocity of light

When a target is moving, doppler frequency f_d obeys the relationship

$$f_d = \frac{2Vdf_0}{C}$$

where

f_0 : transmitted frequency

Vd : relative velocity of target with respect to radar

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When an FM-CW radar receiver simultaneously receives an upper sideband signal and a lower sideband signal of a local oscillator using a homodyne receiver, the interference bandwidth Bw of an FM-CW receiver is

$$Bw \geq 2(f_m + f_d)$$

We assume the radar system parameters to be:

R(maximum) = 100 m
Vd (maximum) = 50 m/s
f_0 = 60 GHz
f_m = 750 Hz
Δf = 75 MHz

From this, we get a Bw is not less than 190 kHz.

3. Acceptable interference power level

The method and speed of modulation depend on the application. Therefore, we assumed that an interference signal is band-restricted white Gaussion noise with bandwidth B.

For FM-CW radar, a received signal frequency changes in the range of Δf. When the bandwidth of an interference signal is less than Δf, a vehicular radar system detects interference if the received signal frequency equals to the interference signal frequency.

If B is less than Δf, the total power of interference signal Pit is

$$Pit = IBw\ /\ \Delta f$$

From that, *Pit* is -54.6 dBm.

If B is not less than Δf, *Pit* is

$$Pit = IBw\ /\ B$$

4. Distance relative to interference

We investigated a distance relative interference in a vehicular radar system. The worst case is:

-The interference source is located in a main lobe of the radar antenna.

-The polarization of the interfering signal is such that it causes the greatest interference possible.

The interference signal power level from the unlicensed device is

$$\Pr i = \frac{PitGiG\,\lambda^2}{(4\pi)^2 Ri^2 La}$$

where

  PitGi : EIRP of the unlicensed device
  Ri : range between the radar and the unlicensed device
  La : attenuation of absorption as a function of *Ri*

Let the system parameters be:

Pr i = -54.6 dBm

$Pit\ Gi$ = 24 dBm

La = 16 dB/Km

The vehicular radar system detects interference from the unlicensed device if the distance between the vehicular radar and the unlicensed device is less than 160 m.

(dBm)

Interference power level of vehicular radar

Radar antenna gain = 36 dB

EIRP = 24 dBm

EIRP = 34 dBm

EIRP = 14 dBm

-54.6 dBm
Acceptable
interference
level
(σ = 10 dB)

Distance between interference source and vehicular radar